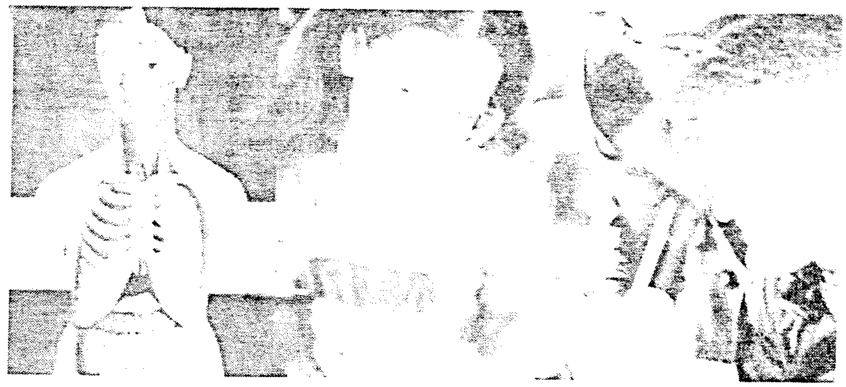
High School Content Expectations



SCIENCE

- Earth and Space
- Biology
- Physics
- Chemistry

RIGOR

RELEVANCE

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Welcome to Michigan's High School Science Content Standards and Expectations

Why Develop Content Standards and Expectations for High School?

In 2004, the Michigan Department of Education embraced the challenge to initiate a "high school redesign" project. Since then, the national call to create more rigorous learning for high school students has become a major priority for state leaders across the country. The Cherry Commission Report highlighted several goals for Michigan including the development of high school content expectations that reflect both a rigorous and a relevant curricular focus. Dovetailing with this call to "curricular action" is Michigan's legislative change in high school assessment. The Michigan Merit Exam, based on rigorous high school learning standards, is to be full implemented by 2007.

The Michigan Department of Education's Office of School Improvement led the development of high school content expectations. A science academic review group of academicians chaired by nationally known scholars was commissioned to conduct a scholarly review and identify content standards and expectations. The Michigan Department of Education will conduct an extensive field review of the expectations by high school, university, and business and industry representatives.

The Michigan High School Science Content Expectations (Science HSCE) establish what every student is expected to know and be able to do by the end of high school and define the expectations for high school science credit in Earth and Space Science, Biology, Physics, and Chemistry.

An Overview

This is a first draft of Science Content Expectations for Michigan High Schools. It was developed by the Science Academic Review Work group. In developing these expectations, the group depended heavily on the *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2006).
In particular, the group adapted the structure of the NAEP framework (including Content Statements, Performance Expectations, and Boundaries). These expectations align closely with the NAEP framework, which is based on *Benchmarks for Science Literacy* (AAAS Project 2061, 1993) and the *National Science Education Standards* (National Research Council, 1996).

The academic review group carefully analyzed other documents, including the Michigan Curriculum Framework Science Benchmarks (2000 revision), the Standards for Success report *Understanding University Success*, ACT's *College Readiness Standards*, College Board's *AP Biology, AP Physics, AP Chemistry*, and *AP Environmental Science Course Descriptions*, ACT's *On Course for Success*, South Regional Education Board's *Getting Ready for College-Preparatory/Honors Science: What Middle Grades Students Need to Know and Be Able to Do*, and standards documents from other states.

Earth & Space Science	Biology	Physics	Chemistry
STANDARDS *(and number of Content Statements in each standard)*			
E1 Systems and Processes in the Environment (4) E2 The Solid Earth (4) E3 The Fluid Earth (4) E4 Earth in Space and Time (9) E5 Chemicals in the Environment (3)	B1 Organization and Development of Living Systems (6) B2 Interdependence of Living Systems and the Environment (4) B3 Genetics (6) B4 Evolution and Biodiversity (3)	P1 Forms of Energy and Energy Transformations (24) P2 Motion of Objects (3) P3 Forces and Motion (10)	C1 Forms of Energy (5) C2 Energy Transfer and Conservation (5) C2 Properties of Matter (10) C3 Changes in Matter (8)

Useful and Connected Knowledge for All Students

This draft defines expectations for Michigan High School graduates, organized by discipline: Earth and Space Science, Biology, Physics, and Chemistry. It defines ***useful*** and ***connected knowledge*** at three levels:

- **Prerequisite knowledge**
  Useful and connected knowledge that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed in the Essential category. Prerequisite content statements and expectations will be included in the middle school science expectations when they are written.
- **Essential knowledge**
  Useful and connected knowledge for all high school graduates, regardless of what courses they take in high school. In general, essential knowledge consists of content and skills that all students need to know and be able to do. Essential content and expectations will be assessable on large-scale assessments (MME/ACT, NAEP).
- **Core knowledge**
  Useful and connected knowledge for students who have completed a discipline-specific course. In general, core knowledge includes content and expectations that students need to be prepared for more advanced study in that discipline.

Useful and connected knowledge is contrasted with ***procedural display***—learning to manipulate words and symbols without fully understanding their meaning. When expectations are excessive, procedural display is the kind of learning that takes place. Teachers and students "cover the content" instead of striving for useful and connected knowledge.

Credit for high school Earth and Space Science, Biology, Physics, and Chemistry will be defined as meeting both essential and core subject area content expectations.

Course / High School Graduation Credit *(Essential and Core Knowledge and Skills)*					Assessment
Earth & Space	**Biology**	**Physics**	**Chemistry**	Formative Assessments	
CORE Knowledge and Skills	**CORE** Knowledge and Skills	**CORE** Knowledge and Skills	**CORE** Knowledge and Skills		
ESSENTIAL Knowledge and Skills	**ESSENTIAL** Knowledge and Skills	**ESSENTIAL** Knowledge and Skills	**ESSENTIAL** Knowledge and Skills		MME / ACT NAEP
Prerequisite Knowledge and Skills					
Basic Science Knowledge Scientific Method Orientation Towards Learning Reading, Writing, Communication Basic Mathematics Conventions, Probability, Statistics, Measurement					

High School Science Overview

Preparing Students for Successful Post-Secondary Engagement

Students who have useful and connected knowledge should be able to apply knowledge in new situations; to solve problems by generating new ideas; to make connections among what they read and hear in class, the world around them, and the future; and through their work, to develop leadership qualities while still in high school. In particular, high school graduates with useful and connected knowledge are able to engage in four key practices of science literacy.

Successful Post-Secondary Engagement

Practices of Science Literacy

Communicate accurately and effectively...

Identifying Science Principles

- Describe, measure, or classify observations
- State or recognize correct science principles
- Demonstrate relationships among closely related science principles
- Demonstrate relationships among different representations of principles

Using Science Principles

- Explain observations of phenomena
- Predict observations of phenomena
- Suggest examples of observations that illustrate a science principle
- Propose, analyze, and evaluate alternative explanations or predictions

Scientific Inquiry

- Generate new questions that can be investigated empirically.
- Design and critique aspects of scientific investigations.
- Conduct scientific investigations using appropriate tools and techniques, recognizing limitations.
- Identify patterns in data and/or relate patterns in data to theoretical models.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions.
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable.
- Gather data and organize the results in graphs, tables, and/or charts.

Reflection and Technology

- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Identify and critique arguments based on scientific evidence.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Propose or critique solutions to problems given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Apply scientific models or patterns in data to technological design decisions.

State/National Landscape

- Expert perspective
- Education reform environment
- Research-based practices
- Work force requirements

State/Federal Expectations

- No Child Left Behind (NCLB)
- National Governors' Association (NGA)
- Legislation/Policy

Michigan High School Science Content Standards and Expectations

Earth and Space Science

Biology

Physics

Chemistry

Models for District Alignment / Mapping

- District curriculum documents
- Documents from other districts/states
- Backmapping to standards and expectations

Other MI Documents/Programs

- State Standards – teaching and learning, content (all areas), assessment
- Grade Level Content Expectations
- State Assessments
- Career/Technical Education
  Department of Labor and Economic Growth

K-8 Educational Experience

Content Knowledge

- English Language Arts
- Mathematics
- Science
- Social Studies
- Other

Learning Processes

- Strategies & Skills
- Reasoning
- Analytical Thinking
- Constructing New Meaning
- Communication

This chart includes talking points for the professional development model.

Practices of Science Literacy

- **Identifying**
  Indentifying performances generally have to do with stating models, theories, and patterns inside the triangle in Figure 1.

- **Using**
  Using performances generally have to do with the downward arrow in Figure 1—using scientific models and patterns to explain or describe specific observations.

- **Inquiry**
  Inquiry performances generally have to do with the upward arrow in Figure 1—finding and explaining patterns in data.[1]

- **Reflecting and Technology**
  Reflecting and *Technology* performances generally have to do with the figure as a whole (reflecting) or the downward arrow (technology as the application of models and theories to practical problems.

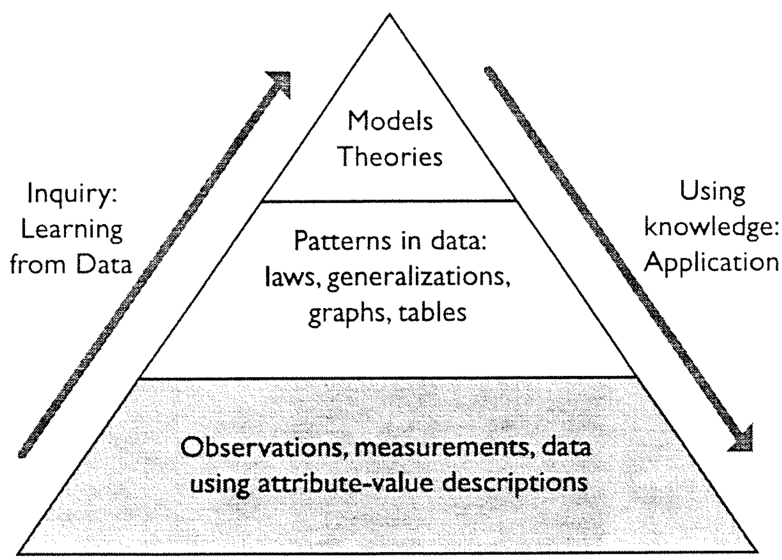

Figure 1: Knowledge and practices of model-based reasoning

Identifying Science Principles

This category focuses on students' ability to recall, define, relate, and represent basic science principles. The content statements themselves are often closely related to one another conceptually. Moreover, the science principles included in the content statements can be represented in a variety of forms, such as words, pictures, graphs, tables, formulas, and diagrams (AAAS, 1993; NRC, 1996). Identifying practices include describing, measuring, or classifying observations; stating or recognizing principles included in the content statements; connecting closely related content statements; and relating different representations of science knowledge.

Identifying Science Principles comprises the following general types of practices:

- Describe, measure, or classify observations (e.g., describe the position and motion of objects, measure temperature, classify relationships between organisms as being predator/prey, parasite/host, producer/consumer)
- State or recognize correct science principles (e.g., "mass is conserved when substances undergo changes of state;" "all organisms are composed of cells;" "the atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor")
- Demonstrate relationships among closely related science principles (e.g., statements of Newton's three laws of motion, energy transfer and the water cycle)
- Demonstrate relationships among different representations of principles (e.g., verbal, symbolic, diagrammatic) and data patterns (e.g., tables, equations, graphs)

Identifying Science Principles is integral to all of the other science practices.

Using Science Principles

Scientific knowledge is useful for making sense of the natural world. Both scientists and informed citizens can use patterns in observations and theoretical models to predict and explain observations that they make now or that they will make in the future.

Using Science Principles comprises the following general types of performance expectations:

- Explain observations of phenomena (using science principles from the content statements)
- Predict observations of phenomena (using science principles from the content statements, including quantitative predictions based on science principles that specify quantitative relationships among variables)
- Suggest examples of observations that illustrate a science principle (e.g., identify examples where the net force on an object is zero; provide examples of observations explained by the movement of tectonic plates; given partial DNA sequences of organisms, identify likely sequences of close relatives)
- Propose, analyze, and evaluate alternative explanations or predictions

The first two categories—***Identifying Science Principles*** and ***Using Science Principles***—both require students to correctly state or recognize the science principles contained in the content statements. A difference between the categories is that Using Science Principles focuses on what makes science knowledge valuable—that is, its usefulness in making accurate predictions about phenomena and in explaining observations of the natural world in coherent ways (i.e., "knowing why"). Distinguishing between these two categories draws attention to differences in depth and richness of individuals' knowledge of the content statements. Assuming a continuum from "just knowing the facts" to "using science principles," there is considerable overlap at the boundaries. The line between the Identifying and Using categories is not distinct.

Scientific Inquiry

Scientifically literate graduates make observations about the natural world, identify patterns in data, and propose explanations to account for the patterns. Scientific inquiry involves the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses to explain patterns in data. Scientific inquiry is a complex and time-intensive process that is iterative rather than linear. Habits of mind—curiosity, openness to new ideas, informed skepticism—are part of scientific inquiry. This includes the ability to read or listen critically to assertions in the media, deciding what evidence to pay attention to and what to dismiss, and distinguishing careful arguments from shoddy ones. Thus, Scientific Inquiry depends on the practices described above—Identifying Science Principles and Using Science Principles.

Scientific Inquiry comprises the following general types of performance expectations:

- Generate new questions that can be investigated in the laboratory or field.
- Design and critique aspects of scientific investigations (e.g., involvement of control groups, adequacy of sample)
- Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision)
- Identify patterns in data and/or relate patterns in data to theoretical models
- Describe a reason for a given conclusion using evidence from an investigation.
- Explain how scientific evidence supports or refutes claims or explanations of phenomena.
- Predict what would happen if the variables, methods, or timing of an investigation were changed.
- Use empirical evidence to validate or criticize conclusions about explanations and predictions (e.g., check to see that the premises of the argument are explicit, notice when the conclusions do not follow logically from the evidence given)
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts.

Scientific inquiry is more complex than simply making, summarizing, and explaining observations, and it is more flexible than the rigid set of steps often referred to as the "scientific method." The *National Standards* makes it clear that inquiry goes beyond "science as a process" to include an understanding of the nature of science (p. 105). Further:

It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations (p. 171).

When students engage in Scientific Inquiry, they are drawing on their understanding about the nature of science, including the following ideas (see Benchmarks for Science Literacy):

- Arguments are flawed when fact and opinion are intermingled or the conclusions do not follow logically from the evidence given
- A single example can never support the inference that something is always true, but sometimes a single example can support the inference that something is not always true
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables
- The way in which a sample is drawn affects how well it represents the population of interest. The larger the sample, the smaller the error in inference to the population. But, large samples do not necessarily guarantee representation, especially in the absence of random sampling

Students can demonstrate their abilities to engage in Scientific Inquiry in two ways: students can *do* the practices specified above, and students can *critique examples* of scientific inquiry. In *doing*, practices can include analyzing data tables and deciding which conclusions are consistent with the data. Other practices involve hands-on performance and/or interactive computer tasks—for example, where students collect data and present their results or where students specify experimental conditions on computer simulations and observe the outcomes. As to *critiquing*, students can identify flaws in a poorly designed investigation or suggest changes in the design in order to produce more reliable data. Students should also be able to critique print or electronic media—for example, items may ask students to suggest alternative interpretations of data described in a newspaper article. For more on item formats, please see Chapter Four.

Reflection and Technological Design

Scientifically literate people recognize the strengths and limitations of scientific knowledge, which will provide the perspective they need to use the information to solve real-world problems. Students must learn to decide who and what sources of information they can trust. They need to learn to critique and justify their own ideas and the ideas of others. Since knowledge comes from many sources, students need to appreciate the historical origins of modern science and the multitude of connections between science and other disciplines. Students need to understand how science and technology support one another and the political, economic, and environmental consequences of scientific and technological progress. Finally, it is important that the ideas and contributions of men and women from all cultures be recognized as having played a significant role in scientific communities.

In both the *National Standards* and *Benchmarks*, the term "technological design" refers to the process that underlies the development of all technologies, from paperclips to space stations. Technological Design describes the systematic process of applying science knowledge and skills to solve problems in a real-world context. The reason for including technological design in the science curriculum is clearly stated in the *National Standards*: "Although these are science education standards, the relationship between science and technology is so close that any presentation of science without developing an understanding of technology would portray an inaccurate picture of science" (p. 190).

Reflection and Technological Design include the following general types of practices, all of which entail students using science knowledge to:

- Critique whether questions can be answered through scientific investigations.
- Identify and critique arguments based on scientific evidence.
- Compare the effectiveness of different graphics and tables to describe patterns, explanations, conclusions, and implications found in investigations.
- Explain why results from a single investigation or demonstration are not conclusive.
- Explain why a claim or a conclusion is flawed (e.g. limited data, lack of controls, weak logic).
- Propose or critique solutions to problems, given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Recognize limitations and use appropriate scientific knowledge in personal, social, political, or economic arguments.
- Apply science principles or data to anticipate effects of technological design decisions.
- Explain the social, economic, and environmental advantages and risks of new technology.
- Discuss the historical, political, environmental, and social factors affecting the developments in science and scientific history.
- Gather, evaluate, and synthesize information from multiple text and non-text sources.
- Discuss topics in groups by making clear presentations, restating or summarizing what others have said, asking for clarification or elaboration, taking alternative perspectives, and defending a position.

Organization of the Expectations

The Science Expectations are organized into Disciplines, Standards, Content Statements, and specific Performance Expectations.

Disciplines

Earth and Space Science, Biology, Physics and Chemistry.

Organization of Each Standard

Each standard includes four parts, described below.

- A standard statement that describes what students who have mastered that standard will be able to do.
- Content statements that describe Prerequisite, Essential, and Core science content understanding for that standard.
- Performance expectations that describe Prerequisite, Essential, and Core performances for that standard.
- Boundary statements that clarify the standards to set limits to expected performances.

Standard Statement

The Standard Statement describes how students who meet that standard will engage in Identifying, Using, Inquiry, or Reflection for that topic.

Content Statements

Content statements describe the Prerequisite, Essential, and Core *knowledge* associated with the standard. This draft identifies five levels of expectations:

1. ***Prerequisite science content*** that all students should bring as a prerequisite to high school science classes. Prerequisite content statements and expectations are listed with Essential content and printed in the left-hand column of the expectations documents.
2. ***Essential science content*** that all high school graduates should master. Essential content and expectations are organized by topic (e.g., E4.2 Earth in Space) and printed in the left-hand column of the expectations documents.
3. ***Core science content*** that high school graduates need for more advanced study in the discipline and for some kinds of work. Core content and expectations are organized by topic (e.g., E4.3x Stars; note that "x" designates a core topic) and printed in the right-hand column of the expectations document.
4. ***Basic mathematics skills.*** These will be included in an Appendix at the end of the document.
5. ***Basic English language arts skills.*** These will be included in an Appendix at the end of the document.

Performance Expectations

Performance expectations are derived from the intersection of content statements and practices—if the content statements from the Earth and Space Sciences, Biology, Physics, and Chemistry are the columns of a table and the practices (Identifying Science Principles, Using Science Principles, Using Scientific Inquiry, Reflection and Technological Design) are the rows, the cells of the table are inhabited by performance expectations.

Performance expectations are written with particular verbs indicating the desired performance expected of the student. The action verbs associated with each practice are not firmly fixed. The use of any action verb must be contextualized. For example, when the "conduct scientific investigations" is crossed with a states-of-matter content statement, this can generate a performance expectation that employs a different action verb, "heats as a way to evaporate liquids."

Boundaries

Boundaries elaborate the Performance Expectations. The boundaries are intended as "notes to curriculum and assessment developers," not as comprehensive descriptions of the full range of science content to be included in the high school science curriculum. In the boundary statements, the terms "such as," "including," "e.g.," and "etc." are used to denote suggestions. The boundaries do not stand alone and should be considered in conjunction with the relevant content statements and narrative introductions for each of the disciplines—Earth and Space Science, Biology, Physics, and Chemistry. Some content statements are very detailed and require less specification of boundaries. Although the boundaries relevant to a given subtopic may focus more heavily on some content statements than others, this is not intended to denote a sense of content priority.